The Five Stage Framework for Life Long Learning in Engineering Education and Practice

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James Uhomoibhi[1] and Margaret Ross[2]

[1]Visiting Professor of Computer Science and Information Technology at Igbinedion University, Okada, Nigeria, The Open University of Tanzania and past E-Learning Co-ordinator at University of Ulster, Faculty of Computing and Engineering, Co Antrim BT37 0QB, Northern Ireland, UK,
j.uhomoibhi@ulster.ac.uk

[2]Professor of Software Quality, Solent University, School of Media Art and Technology, East Park Terrace, Southampton, Hampshire, SO14 0RD, UK,
Margaret.Ross@solent.ac.uk

Abstract

This paper examines and reports on a five-stage framework for lifelong learning in engineering education and practice. The paper draws on the authors' experiences in their universities and working with the local communities. The five stages are: Pre-employment (undergraduate stage, including the need for continuously updated CV); Early Employment; Mid-Career Employment; Later Employment (usually at the more senior level of the employment and preparing for up-skilling after retirement) and Post Employment (retired). The paper discusses and justifies, for each of the different stages, the appropriate activities such as involvement with professional societies, updating, both in breadth and depth, technical knowledge and soft skills, utilising SFIAplus or similar frameworks, the use of webinars and MOOCs, also the changing role of mentors, from mentee to mentor, throughout the stages. The involvement at various stages of related voluntary activities such as "giving back" to the profession are considered.

Keywords: Lifelong Learning, Professional Bodies, Networking Updating Skills, Engineering Education and Practice

1.0 Introduction

A framework for engineering education and practice has been created to meet the growing need for a clear definition of quality used in guiding curriculum development, classroom implementation, policy and standards in this current era of globalization. It is important that informed decisions guide the future about how engineering is implemented globally.

Engineering education and practice has been used to describe pre-college (secondary), university (higher education) and post-graduation (employment) knowledge and skills in society aimed at improving lives of individuals and communities. This, in recent times, has been integrated with STEM (Science Technology Engineering and Mathematics) subjects. STEM integration has the potential to provide learners with best opportunities. There is a natural interconnectedness of each of these four components of STEM in the real world of research and development, which affects students' interests and performance [1,2]. Engineering provides a way of meaningfully integrating STEM disciplines as it requires application of mathematics and sciences in the design and development of technologies, products and services for people and communities.

The authors use a five-stage framework to define and report on lifelong learning in engineering education and practice. The five stages comprise 1st Pre-employment (undergraduate stage, including the need for continuously updated curriculum vitae throughout the stages); 2nd Early Employment; 3rd Mid-Career Employment; 4th Later Employment (usually at the more senior level of the employment and preparing for up-skilling after retirement); and finally, 5th Post Employment (retired). The research examines issues of students, staff aspirations, the provisions of professional organisations and expectations right across the spectrum including employment and post-employment practice. The paper describes how the experiences of the authors and others identifies the five stages for lifelong learning based on their experiences in their universities and working with the local communities and professional organisations in the UK, Europe and Africa. This includes the innovations in teaching and learning and studying approaches developed and used.

With the constant change in engineering and technology of hardware, software, and applications, ranging from medical to cyber warfare, there is a constant need for professionals to maintain the currency of their knowledge throughout their lives [3,4,5]. This is required, not only by employers and individuals, but also by various professional institutions. This could involving maintaining an annual report, providing evidence to demonstrate their current skills and knowledge. These include an up-to-date CV documenting any CPD activities undertaken in the last year such as training courses and qualifications gained. The report could include examples of work based learning; professional activity, such as involvement in a professional body or mentoring; formal or educational activities such as writing articles or papers, or undertaking further education; self-directed learning such as reading journals, reviewing books or articles; other activities such as voluntary work or public service. In addition, the report for the Institue of Science and Technology also might

"provide examples of how your CPD has contributed to the quality of your professional practice and service delivery" and also in this report there is the request "to provide examples of how your CPD activity has benefitted the users of your work".

Some professional bodies ask their members to confirm, with the renewal of their membership, that their knowledge is current. This is normally encompassed in the Code of Conduct of the various professional bodies. An example of this is from the CIOB (Chartered Institute of Building) which states in its Code of Conduct [6] that "members shall keep themselves informed of current thinking and developments appropriate to the type and level of their responsibility. They should be able to provide evidence that they have undertaken sufficient study and personal development to fulfil their professional obligations in accordance with the current guidelines for Continuing Professional Development (CPD)". Similarly the Code of Conduct of the BCS [7] states that a member must "develop your professional knowledge, skills and competence on a continuing basis, maintaining awareness of technological developments, procedures, and standards that are relevant to your field" and "encourage and support fellow members in their professional development ".

There are many ways in which these skills can be updated, such as by reading journals, attending courses and conferences, but it is much more difficult to always provide evidence of the updating of relevant knowledge and skills that have been achieved, unless some form of assessment has been undertaken. The record of CPD whether paper based, or electronically held, such as with Open Badges [8], does at least provide a record of suitable attendance of up-skilling activities. The CPD activities can be provided in many different ways from traditional trainers to universities and colleges.The paper concludes with some recommendations with the note of the need to engage learners and employers in the lifelong learning process very early on in what has now become an ever-changing learning landscape of the globalised 21st Century.

2.0 Lifelong Learning and Engineering Education and Practice

Lifelong learning is a process of engaging in formal and informal education on an ongoing basis and ensuring that a person is equipped with the skills and abilities required to continue his or her own self-education beyond the end of formal schooling. In the past two decades since the turn of the 21st century, research on lifelong learning has accelerated as educators and policy makers globally are faced with the task of converting concepts into programmes. Lifelong learning has not only found roots during formal education but tended to go hand in hand in the creation of well-rounded engineers. Lifelong learning is a purposeful self-directed learning process that plays vital role in lives of individuals, through enhancing the quality of the learner's life and improving their economic standing. Engineering is the

discipline that helps build society. It is therefore important that institutions and government invest and provide lifelong learning opportunities and robust programmes that allows engineers and engineering professions to engage in lifelong learning throughout life.

The US Accreditation Board for Engineering and Technology (ABET) defines engineering as "The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation or safety to life and property". It must be noted that engineering is best understood in relation to other disciplines [9,10]. Lifelong learning seeks to provide citizens with tools for personal development, social integration and participation in the knowledge economy. This should be applied across all levels of education and training and relates to all stages of life and must be reflected in strategies of governments, professional bodies and associated institutions to enable and make lifelong learning an integral part of the whole educational system, including the entire social and economic structure.

3.0 The Framework

This paper discusses the need for a five-stage framework, to encourage CPD being undertaken at all periods from college or university, through the various phases of employment, including post-employment period. With the increased life-expectancy, skills in this later stage could be important for a country's economy, for those engaged in paid or voluntary (unpaid) employment and particularly for local organisations and charities.

The content of the proposed framework could be related to career structures such as SFIAplus [11] for the computing industry. This provides, for all stages from the apprenticeship to the most senior level that might be a head of department, MD (Managing Director) or CIO (Chief Information Officer) of a large organisation. It identifies, for a range of specific employment roles, the various functions that might be undertaken, the skills and knowledge needed and potential qualifications. The range of skills needed, including the soft skills, change and develop as the career progresses and the awareness of the roles locally, within the company, country, and globally increase with the levels. This framework for lifelong learnibg takes a holistic view of the range of possible CPDs appropriate to the different stages of employment, such as can be applied to or adapted for all emerging disciplines.

3.1 Pre-Employment (Stage 1)

This is normally undertaken at a college or university. The majority of technology courses, especially those that are designed to satisfy the requirements of the relevant professional bodies, include the teaching of various issues of professional practice. This normally includes academic writing, with the correct use of references, relevant legal and ethical standards, and the need to develop and maintain throughout the students' future career, a CV (Curriculum Vita). This would include both the

academic skills and qualifications, as well as the relevant and non-relevant related experience, (such as working in a supermarket, volunteering for a charity), together with the students' interests. The students would be made aware that they must take responsibility to keep their CV up-to-date throughout their future career, and possibly beyond into retirement.

Students are often encouraged to attend, in addition to their course, lectures arranged by external bodies, such as the various professional bodies. Students are also encouraged to collect their CPD form as a proof of their attendance or, if a CPD form is not available, to make a record of the event including the title, speaker, general topic as well as the date, location and organising body. It is suggested that the students keep these CPD forms or their own equivalent details, either in paper form or as an electronic version, and to maintain these records well into their mid-career. These could prove to be useful for future reference prior to interviews, applications for employment or up-grading their professional status. Students are often encouraged to join the relevant professional bodies as a student member.

Some universities arrange for students to undertake professional qualifications or include these qualifications within the structure of the course. An example of this is the CISCO qualifications, often associated with networking undergraduate courses. These students, as part of their degree, would also achieve the externally recognised professional qualification. This is of benefit to the students as these professional qualifications enhance their CV, and also to their potential employers, who often understand the skills required by the professional qualifications in more detail than the actual content of a particular degree course.

By encouraging the students to undertake these additional external qualifications, these students understand that, regardless of the support or otherwise of their future employer, they can continue their accredited learning, possibly with a change of direction, independently of their employer if necessary. Students are encouraged to join events of the relevant professional institutions, and by attending regularly, they can increase their networking skills and possibly join a committee or a sub-committee, possibly as a student representative of a local professional group.

3.2 Early-Employment (Stage 2)

On starting employment, the planning and organisation of activities to add new skills and knowledge are usually controlled by the employer, often being initiated by a "need to know now" requirement for the particular employee. The employer will maintain usually through the Human Resource Department, a record of the training undertaken, but it is wise for the employee, especially in the early career, to maintain their own personal records. This would include both the formal and informal training received, as well as attendance at such activities as user groups, seminars, conferences and events of professional bodies. It is useful to also maintain on this "extended CV" details such as involvement in voluntary activities, which might include visiting undergraduate career fairs to represent their employers or their professional body or going to talk to school pupils about careers in the STEM sector.

Formal courses could be organised by the employer, varying from day release, to a few days or several weeks duration. These are highly structured, leading often to further assessment of the knowledge learnt. The employee, could independently of the employer, undertake a distance learning course, with possible occasional weekend or weeks attendance such as those organised in the UK by the Open University whose courses can lead to awards of an undergraduate or Master's degree. Remote study can be undertaken often at no or low cost by following an online MOOC (Massive Open On-line Course). These are usually provided by a number of well-known universities where assistance with the structured study material is provided often by online peer discussions between those following that particular MOOC. It usually has no recognised qualification for the attendees of these courses, unless they request this from the appropriate university and undertake assessments such as examinations, at a fee, organised by the university. Additional knowledge can be achieved by participating in online webinars, which are often free and can be accessed also after the event. By becoming actively involved in the discussions whether in the webinar or at a face-to-face event, this can help to improve the soft skills of the employee which will become even more important as they progress through their career.

During this period, the employee could become more involved with their professional body, both by regularly attending events, and possibly joining committees or sub-committees. This would increase the networking opportunities of the employee as well as possibly becoming aware of potential new job opportunities. They could utilise from the early career stage, the identification of the functions, skills and training from models such as SFIAplus [11] relating to progressing to the next level of their career. The employee can identify possible missing skills and at their next annual job appraisal meeting, are able to raise the need for suitable training. Otherwise the employee can undertake independent activities to add the necessary skills and experience. These should always be documented in an extended CV, and full records maintained of CPD undertaken. Early stage employees can be mentored by a more senior member of their organisation which would normally assist in their CPD and career progression.

During the early career, or even prior as a student, many decide, in addition to joining a relevant professional society, such as the BCS, The Chartered Institute of IT, the IET, the IEEE , the IST (Institute of Science and Technology) or the ACM. The range of membership is usually, Student, Member and Fellow, the latter only usually achieved towards the end of the mid-career or during later employment, as it is often dependent on level of responsibility, authority and experience. The advantages of professional membership are both the networking opportunities and the possibility to "give back" to the profession. This might be to encourage students, at school, college or university, to understand the applications and the opportunities in the STEM areas. It could be assisting with organising events, on being members of committees or on Standards Bodies, the latter might be towards the end of the mid-career stage or later stages.

3.3 Mid-CareerEmployment (Stage 3)

During this mid-career stage, the employee might undertake the role of a mentor to a new employee within the same organisation. However, the mid-career stage employee might wish to become themselves a mentee and have a mentor from outside their organisation at a more senior level. These arrangements are often facilitated by professional bodies for their members. The guidance from the mentor might be related to up-grading the professional membership status or applying to join county, regional or even national committees within or outside their professional body. The guidance from the mentor would suggest actions or activities to prepare the mentee for such roles in the future. The mentor could encourage long-term planning of the mid-career employee, including possible changes of direction and of employer. Proposals might be made to undertake additional technical or managerial qualifications such as the MBA (Master of Business Administration), that could be of advantage for current and future career levels. The mid-stage employee might consider participating in relevant MOOCs and webinars, in addition to perhaps speaking at conferences, and at local and regional events organised by relevant professional bodies. This would increase the networking opportunities; improve the soft skills, as well as the CPD. These activities would be of great benefit if the employee was considering becoming an independent contractor or consultant, where the external profile is of importance.

In the mid-stage of a career, in addition to professional membership, being normally at full Member or Fellow level, obtaining a Chartered status through the professional body can be considered. The three main ones are the Engineering Council's CEng (Chartered Engineer), the Science Council's CSci (Chartered Scientist) and the BCS's CITP (Chartered IT Professional). Many of the STEM institutions assist their members to obtain only one or two of these. In all three cases, the level of responsibility and experience is approximately the same, but there is a difference on the type of experience and qualification required for each of them. For the CITP, the candidate is expected to demonstrate a breadth and also a depth of knowledge in the relevant area, and a certificate of competence can be renewed every three years. For the CEng, the candidate is expected to maintain the currency of their knowledge. The CSci requires annual records of PPD (Professional and Personal Development), which can be audited every three years. The details regarding these records of the CPD activities can vary for the different institutions.

3.4 Later Employment (Stage 4)

At this point of the career, the employee could hold a senior position in their organisation and possibly in their professional body. The need to maintain current awareness of the changes in the profession, both current and predicted, is particularly important. The employee will be using the soft skills as a possible representative of their organisation or of their professional body on national or international committees, as speakers at conferences or being interviewed by the media. At this stage in the career, the employee or self-employed might become an external mentor to those in mid-career. The mid-stage employee could be participating as a panel member of a webinar or perhaps running a blog.

The employee might be participating in various voluntary activities, in preparation for the final stage of retirement. These might be becoming involved, possibly as independent governors of schools or colleges, or becoming involved with local centres where their technical and managerial expertise could be of value. In these cases, the employee could be "giving back" to the profession, by the voluntary use of their time, which still should be recorded in their CPD. In order to encourage the participation in these activities, the employee might consider becoming a "life member" of their professional body or of any other society of which they might wish to be involved with during their retirement.

3.5 Post Employment (Stage 5)

By maintaining awareness of the constantly changing technical developments and new potential developments in the engineering field, this can be beneficial to the retired employee as a possible action against dementia, lethargy and boredom. Continuing to "up skill" can be undertaken at little cost via short courses with or without qualifications, by participating in MOOCs and webinars. At this stage, the employee could, already from the later employment stage, be running or being a Chair or Panel member of a webinar. Further involvement, locally, regionally, nationally or internationally with the professional bodies can be welcomed as those not in restricted time constraints of employment are often of great benefit to a professional body and to voluntary organisations. The retired employee could become an unpaid lecturer for charities such as the University of the Third Age, as well as assisting as a visiting speaker at schools or colleges. The use of the TV and Internet can provide regular means for both entertainment and education for those in this 5th stage.

4.0 Benefits of the Framework

There are lot of benefits that can arise from the use of the current framework and stages identified. Its application at different levels could helped researchers assess usefulness with younger students in elementary or fundamental stages and settings, which would contribute to increase the understanding of how the framework could be useful in the classroom. It could inform development of curricula, classroom implementation, standards, and policy around engineering as we look towards how engineering currently is and should be implemented at different levels in the future.

The framework could be used to assess the status of STEM global academic standards and also how this is being applied to different national technical education in order to map and gain a picture of how technology is currently being represented in different educational systems [12,13,14]. There is the potential for the current framework to be used in developing units of instruction as well as for developing scope and sequencing throughout the curricula. It could act as a guide to ensure curricular units truly represent the complexities of STEM professional development and lifelong learning.

5.0 Diversity, Transdisciplinarity and Holistic Engineering Education and Practice

The embedding of inclusion and diversity in programmes makes for holistic engineering education and practice. It allows for trans-disciplinarity that is important for the development of future-oriented, sustainable and socially responsible engineers who are able to produce technical solutions and innovations that have societal and economic added value [15].The development and use of this technology in context for the provision of holistic engineering is crucial. It has been shown that programmes planned and delivered with features in the model enable students to become confident in working with different people, cultures and in different places [16]. This promotes understanding and encourages respect among learners in institutions and employees in the workplace, all of which increases the level of engagement, productivity and success and profitability. The needs of diverse groups are met. It encourages the development and adoption of best practice.

There are serious issues in putting lifelong learning into engineering education practice. One of them is the diverse nature of the educational system of each country, which is not yet prepared always to develop lifelong learning competences. This remains a major challenge to the many educational systems that have not changed their educational policies and pedagogical models to support lifelong learning. Another issue is the one of time constraints in the delivery of the various focused curricula across many educational settings. In Europe and USA this could correspond to Bologna and ABET frameworks directed at meeting the expectations of the rapidly changing and very different environments as implied by lifelong learning concept. There are others such as the BCS, the Chartered Institute for IT, the Institution for Engineering and Technology (IET), the African Engineering Education Association (AEEA), The European Society for Engineering Education (SEFI), the framework of The International Society for Engineering Education (IGIP) etc. This is an obvious indication that a change in education is needed. [17,18,19].

Such a change must be made up of educational processes that will strive for the capability of adapting, and even thriving in areas of new problems and new opportunities, requiring schools to look across disciplines, across the knowledge base of sciences, across the wisdom of the humanities, the verities and explorations of the arts, for the ingredients that will enable students to continually interact with a world in change, with the imminence of changes bringing essentially unforeseeable consequences [20]. The introduction of such a change has the potential to create a process that would result in collaboration among individuals and institutions from diverse disciplines and regions to develop and use integrated conceptual frameworks, tools, techniques and methodologies to solve common unstructured research problems relevant to industry and society.

6.0 Conclusion

Engineering education and practice engages in lifelong learning which provides opportunities to learn at the beginning stages and later extending into turning individuals into accomplished professionals and entrepreneurs [21]. In the context of lifelong learning, the teacher as a catalyst must turn knowledge into metaskills. This has the potential to meet the needs of learners in the twenty-first century, with reference to the development of individual capability, individualized learning and independent learning. The focus of the authors' research and the themes presented addresses issues concerning engineering education and lifelong learning, both of which require multidisciplinary approach involve fields from engineering, education, psychology and the world of work. The link between education, lifelong learning and employment is real and desirable. It is imperative that solutions are found not only for education but for practitioners and the world of work.

The five-stage framework for lifelong learning in engineering education and practice offers a collection of key indicators for a comprehensive engineering education at different levels and a means to develop those key indicators through systematic definitions of each indicator. The framework has potential as a research instrument that can lead to deeper understandings of learning and instruction in engineering education and impacts on the practitioners and industry. Further work ise in progress involving implementation of the framework in different parts of the world to include the UK, parts of Europe and Africa.

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